SPIN RELAXATION OF SPIN DENSITY FLUCTUATIONS IN LIQUIDS

V.J. SHURIGIN and R.M. YULMETYEV
Kazan Pedagogical Institute, Kazan 420021, USSR

Received 29 June 1989; accepted for publication 31 August 1989
Communicated by J.I. Budnick

Relaxational kinetics of spin density fluctuations in liquids is considered by the method of projection operators. It is shown that the description of magnetic relaxation on the basis of spin density fluctuations gives the most detailed picture of relaxational phenomena.

1. At the present time the methods of density matrix, nonequilibrium statistical operator, kinetic equation for the time correlation function (TCF) of separate components of the magnetization (see for example refs. [1–5]) are widely used to describe spin relaxation in liquids and solutions. Such an approach is close to macroscopic, since in this case the kinetic description of the system as a whole is achieved. At the same time, however, some details connected with the peculiarities of spin kinetics in small volumes of a sample are lost. They become apparent, when we are analysing spin relaxation in terms of spin density fluctuations of the system,

$$\delta\hat{S}_\alpha(\boldsymbol{k},t)=\sum_{j=1}^{N}\{\hat{S}_\alpha^{(j)},\exp[\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{r}_j(t)]\}-\langle\hat{S}_\alpha(\boldsymbol{k},t)\rangle\delta_{\boldsymbol{k},0},\quad \alpha=0,\pm1\,, \tag{1}$$

where $\hat{S}_0^{(j)}=\hat{S}_z^{(j)}$, $\hat{S}_\pm^{(j)}=\hat{S}_x^{(j)}\pm\hat{S}_y^{(j)}$, $\{\hat{A},\hat{B}\}=\frac{1}{2}(\hat{A}\hat{B}+\hat{B}\hat{A})$, and $\delta_{\boldsymbol{k},0}$ is the Kroneker symbol.

Let us consider the normalized TCF of spin density fluctuations,

$$\mu_\alpha(\boldsymbol{k},t)=\frac{\langle\delta\hat{S}_\alpha^*(\boldsymbol{k},0)\delta\hat{S}_\alpha(\boldsymbol{k},t)\rangle}{\langle\delta\hat{S}_\alpha^*(\boldsymbol{k},0)\delta\hat{S}_\alpha(\boldsymbol{k},0)\rangle}\,. \tag{2}$$

The following exact kinetic equation for the TCF $\mu_\alpha(\boldsymbol{k},t)$ was obtained in ref. [6] by the method of projection operators [7,8],

$$\frac{\mathrm{d}\mu_\alpha(\boldsymbol{k},t)}{\mathrm{d}t}=-\mathrm{i}\alpha\omega_0\mu_\alpha(\boldsymbol{k},t)-\int_0^t\mathrm{d}\tau\,[K_\alpha^{(1)}(\boldsymbol{k},\tau)+K_\alpha^{(2)}(\boldsymbol{k},\tau)]\mu_\alpha(\boldsymbol{k},t-\tau)\,, \tag{3}$$

$$\omega_0=\frac{\langle\delta\hat{S}_\alpha^*(\boldsymbol{k},0)\hat{L}_s\delta\hat{S}_\alpha(\boldsymbol{k},0)\rangle}{\langle\delta\hat{S}_\alpha^*(\boldsymbol{k},0)\delta\hat{S}_\alpha(\boldsymbol{k},0)\rangle}\,,$$

$$K_\alpha^{(1)}(\boldsymbol{k},\tau)=\frac{\langle[\delta\hat{S}_\alpha^*(\boldsymbol{k},0),\hat{H}_1]\exp(\mathrm{i}\hat{L}_{22}\tau)[\hat{H}_1,\delta\hat{S}_\alpha(\boldsymbol{k},0)]\rangle}{\hbar^2\langle\delta\hat{S}_\alpha^*(\boldsymbol{k},0)\delta\hat{S}_\alpha(\boldsymbol{k},0)\rangle}\,,$$

$$K_\alpha^{(2)}(\boldsymbol{k},\tau)=\frac{\langle\hat{T}_\alpha^*(\boldsymbol{k},0)\exp(\mathrm{i}\hat{L}_{22}\tau)\hat{T}_\alpha(\boldsymbol{k},0)\rangle}{\langle\delta\hat{S}_\alpha^*(\boldsymbol{k},0)\delta\hat{S}_\alpha(\boldsymbol{k},0)\rangle}\,,$$

$$\hat{T}_\alpha(\boldsymbol{k},t)=\sum_{j=1}^{N}\{\hat{S}_\alpha^{(j)},[(\boldsymbol{P}_j\cdot\boldsymbol{k})/m]\exp(\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{r}_j)\},\quad L_{22}=P_\alpha\hat{L}P_\alpha,\quad P_\alpha=1-\Pi_\alpha\,,$$